

HIGH-FREQUENCY ELECTROMAGNETIC MEASUREMENTS FOR ENVIRONMENTAL APPLICATIONS

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RESEARCH OBJECTIVES

High-resolution imaging of the shallow subsurface is a valuable tool for delineation of buried waste, detection of unexploded ordinance, verification and monitoring of containment structures, and other environmental applications. To this end, we have been developing a non-invasive methodology for accurately imaging the electrical conductivity and the dielectric constant (normalized electrical permittivity) of the shallow subsurface using the high-frequency impedance (HFI) approach.

APPROACH

Studies have shown that electromagnetic (EM) measurements at frequencies between 1 and 100 MHz are important for such applications to determine the dielectric constant in addition to electrical conductivity of the subsurface. For high-resolution imaging, accurate measurements are necessary so the field data can be mapped into the space of the subsurface parameters. To achieve accurate measurements, electric and magnetic sensors have been tested in a known area against theoretical predictions. For the transmitter, we used a function generator good to 30 MHz and an amplifier with a bandwidth of 250 kHz through 110 MHz. We also built and tested electric & magnetic transmitter antennae good through at least 30 MHz. To minimize spurious pickup and parasitic radiation, coaxial cables have been replaced by optical fibers. Additionally, we set up and tested a digital data acquisition system that operates under control of a notebook computer through a GPIB interface.

In the initial development of the field system and its verification, measurements were made at the Richmond Field Station (RFS), operated by the University of California at Berkeley. The measured impedance showed good agreement with calculated values through 10 MHz. Conditions at the RFS are relatively conductive and the EM impedance is more sensitive to the subsurface conductivity. In a more resistive environment, such as the Savannah River Site clay caps, model studies show that the impedance is more sensitive to the subsurface permittivity. Two attempts at securing high-frequency impedance data in a resistive environment have been made to date. The first attempt was at Donner Summit in the Sierra Nevada Range. Initial analyses show that the impedance data agree well with a simple homogeneous earth model. The second attempt was made in a very highly resistive environment at Point Reyes National Seashore. Near-surface resistivities of 2,000 to 10,000 ohm-m have been measured.

ACCOMPLISHMENTS

Following the initial sensor verification done last year for the frequency range of up to a few MHz, the project moved on to a wider portion of the radio spectrum, up to 30 MHz to date. This step required development of a transmitter system in order to have a signal at specified frequencies.



Figure 1. Toroid, a high-frequency electric field sensor. The device measures electric field in the direction parallel to the toroid axis. One shown here has 100 windings, and the size is 3" OD (compare with the quarter on the right).

Additionally, we have refined the behavior of the toroid (Figure 1), a compact high-frequency electric field sensor. Improvements in the shielding and extraneous pickup problems with the prototype toroid have led to an improved response.

SIGNIFICANCE OF FINDINGS

High-frequency measurements of up to 30 MHz have been made in terms of EM impedance for the first time. This is a critical frequency band (up to 100 MHz) that contains information about the electrical property, both dielectric constant and electrical conductivity, of the shallow subsurface.

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